EFFECT OF DIFFERENT RATES OF POTASSIUM INCORPORATED WITH CHICKEN MANURE BIOCHAR ON THE GROWTH, YIELD AND EATING QUALITY OF SWEET CORN (*Zea mays L.)*

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ABSTRACT

This study study was carried out at the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah (UMS) Sandakan Campus from June to September 2016 to evaluate the effect of potassium (90:60:40, 90:60:50, 90:60:60, 90:60:70, 90:60:80, and 90:60:90) incorporated with application of chicken manure biochar (20 t ha^{-1}) on the growth, yield and eating quality of Improved Mas Madu sweet corn planted on Silabukan soil. The nutrient content for Silabukan soil series was also investigated after the experiment. The treatments that involved in this study were control (NPK 90:60:60 kg ha^{-1} without chicken manure applications), chicken manure biochar treatment and six different rates of potassium fertilizer which were 40 kg ha^{-1}, 50 kg ha^{-1}, 60 kg ha^{-1}, 70 kg ha^{-1}, 80 kg ha^{-1} dan 90 kg ha^{-1} while the rate of application for chicken manure biochar were 20 t ha^{-1} incorporated with each treatment. These treatments were arranged as a one-way completely randomized design (CRD) with five replications. Data collected were analysed using one-way anova at 5% significant difference. The results showed that for vegetative growth of Improved Mas Madu sweet corn crop, treatment T7 gave the tallest plant height and the most amount of leaf number's which were 260.24 cm and 11.2, respectively. Treatment T5 showed the highest first cob height from soil surface which was 123.9 cm. For the yield component, treatment T2 gave the longest length of cob that was 17.08 cm whereas treatment T5 gave the heaviest wet weight of cob which was 114.02 g. Treatment T7 gave the longest diameter of cob and cob girth which were 4.02 cm and 12.63 cm, respectively. Treatment T2 gave the most number of grains per cob which was 405 grains and treatment T3 gave the heaviest weight of 100 grains per cob which was 10.12 g. Furthermore, treatment T7 gave the highest extrapolated dried cobs yield which was 3.35 tonnes per hectare and treatment T3 gave the highest extrapolated grain yield which was 1.77 tonnes per hectare. For mean root dry weight, treatment T6 showed the heaviest mean root dry weight which was 36.9g. For the total soluble solids content, treatment T4 gave the highest brix reading which was 19.13 °brix. For Silabukan's soil chemical properties, treatment T7 had the highest pH value and total nitrogen content by which 6.16 and 2.18%, respectively, meanwhile treatment T5 had the highest available phosphorus which was 1.846 ppm. This experiment revealed that treatment T1 (control) gave the shortest plant height, least mean number of leaves, shortest length of cob, lowest weight of cob, shortest diameter of cob, shortest cob girth, least number of grains, lowest weight of 100 grains, lowest extrapolated dried cob yield, lowest extrapolated grain yield and lowest total soluble solid content which were 76.2 cm, 9.8 mean leaves, 12.34 cm, 59.15 g, 2.79 cm, 8.76 cm, 201 grains, 4.74 g, 1.98 tonnes per hectare, 1.41 tonnes per hectare and 16.93°brix content, respectively. Meanwhile, treatment T2 gave the shortest first cob height from soil surface which was 85.04 cm. Thus, the best treatment that can be recommended to the farmers is treatment T7 (90:60:90 NPK kg ha^{-1} incorporated with 20 t ha^{-1} chicken manure biochar) because the treatment had highest extrapolated dried cobs yield, 3.35 tonnes per hectare and longest cob girth, 12.63 cm. Besides, the second best treatment that can be recommended was treatment T5 (90:60:70 NPK kg ha^{-1} incorporated with 20 t ha^{-1} chicken manure biochar) because this treatment had the heaviest weight of cob, 114.02 g and the third highest for extrapolated dried cobs yield, 2.66 tons ha^{-1}.

KESAN KADAR KALIUM YANG BERBEZA DIGABUNGKAN DENGAN BAJA NAJIS AYAM BIOCHAR TERHADAP PERTUMBUHAN, HASIL DAN KUALITI MAKANAN JAGUNG MANIS (Zea mays L.)

ABSTRAK

Kajian ini telah dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah (UMS) Kampus Sandakan bermula daripada bulan Jun hingga September 2016 untuk mengkaji kesan campuran pemberian potassium (90:60:40, 90:60:50, 90:60:60, 90:60:70, 90:60:80 dan 90:60:90 kg ha^{-1}) dicampurkan dengan baja organik najis ayam biochar (20 t ha^{-1}) terhadap pertumbuhan, hasil dan kualiti makanan jagung manis Improved Mas Madu yang ditanam pada tanah Silabukan. Kandungan tanah siri Silabukan juga dikaji selepas eksperimen. Rawatan yang terlibat dalam kajian ini adalah terkawal (NPK 90:60:60 kg ha^{-1} tanpa penggunaan baja najis ayam biochar), rawatan najis ayam biochar dan enam pemberian kadar berbeza baja potassium iaitu 40 kg ha^{-1}, 50 kg ha^{-1}, 60 kg ha^{-1}, 70 kg ha^{-1}, 80 kg ha^{-1} dan 90 kg ha^{-1} manakala kadar baja organik najis ayam biochar adalah 20 t ha^{-1} bagi setiap satu rawatan. Rawatan-rawatan ini diatur menggunakan reka bentuk rawak secara keseluruhan (CRD) dengan lima replikasi. Data yang dikumpul dianalisa menggunakan ANAVA satu-hala pada keertian 5%. Keputusan bagi pertumbuhan vegetatif tanaman jagung manis Improved Mas Madu menunjukkan rawatan T7 menghasilkan pokok tertinggi dan bilangan daun terbanyak iaitu masing-masing 260.24 cm dan 11.2 min daun. Rawatan T5 menghasilkan jarak tongkol pertama dari permukaan tanah tertinggi iaitu 123.9 cm. Untuk komponen hasil, rawatan T2 menghasilkan tongkol jagung terpanjang iaitu 17.08 cm manakala rawatan T5 menghasilkan tongkol jagung basah terberat iaitu 114.02 g. Rawatan T7 menghasilkan diameter tongkol jagung terpanjang dan ukur lilit tongkol jagung terpanjang iaitu masing-masing 4.02 cm dan 12.63 cm. Rawatan T2 menghasilkan bilangan butir jagung per tongkol terbanyak iaitu 405 butir dan rawatan T3 menghasilkan berat 100 butir jagung per tongkol tertinggi iaitu 10.12 g. Tambahan pula, rawatan T7 menghasilkan unjuran hasil tongkol jagung terberat iaitu 3.35 tan per hektar dan rawatan T3 menghasilkan unjuran hasil butir jagung tertinggi iaitu 1.77 tan per hektar. Untuk purata berat kering akar, rawatan T6 menunjukkan purata berat kering akar terberat iaitu sebanyak 36.9g. Untuk jumlah kandungan pepejal terlarut, rawatan T4 menhasilkan kandungan brix tertinggi iaitu 19.13°brix. Untuk kandungan kimia tanah Silabukan, rawatan T7 menunjukkan nilai pH dan jumlah kandungan nitrogen iaitu masing-masing 6.16 dan 2.18%. Kajian ini juga menunjukkan bahawa rawatan terkawal T1 menghasilkan pokok terendah, min bilangan daun tersedikit, saiz tongkol jagung terpendek, berat tongkol jagung paling ringan, diameter tongkol jagung terpendek, ukur lilit tongkol jagung terpendek, bilangan butir jagung per tongkol tersedikit, berat 100 butir jagung paling ringan, unjuran hasil tongkol jagung terendah, unjuran hasil butir jagung terrendah dan jumlah kandungan pepejal terlarut terendah iaitu masing-masing 76.2 cm, 9.8 min daun, 12.34 cm, 59.15 g, 2.79 cm, 8.76 cm, 201 butir jagung, 4.74 g, 1.98 tan per hektar, 1.41 tan per hektar dan 16.93° kandungan brix. Selain itu, rawatan T2 menghasilkan jarak tongkol pertama daripada permukaan tanah terendah iaitu 85.04 cm. Oleh itu kadar terbaik yang dicadangkan kepada para petani ialah rawatan T7 (90:60:90 NPK kg ha^{-1} digabungkan dengan 20 t ha^{-1} baja najis ayam biochar) kerana rawatan tersebut mempunyai penghasilan tongkol tertinggi, 3.35 tan per hektar dan ukur lilit tongkol jagung terpanjang, 12.63 cm. Selain itu, rawatan kedua yang dicadangkan ialah rawatan T5 (90:60:70 NPK kg ha^{-1} digabungkan dengan 20 t ha^{-1} baja najis ayam biochar) kerana rawatan ini mempunyai berat tongkol jagung tertinggi, 114.02 g dan ketiga tertinggi antara kesemua rawatan bagi penghasilan tongkol, 2.66 tan per hektar.

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%	Percentage
ANOVA	Analysis of Variance
CRD	Completely Randomized Design
CEC	Cation Exchange Capacity
FAO	Food and Agricultural Organization
FSA	Faculty of Sustainable Agriculture
K2O	Potassium Oxide
LSD	Least Significant Difference
P2O5	Phosphorus Pentoxide
r	Radius
SAS	Statistic Analysis Software

CHAPTER 1

INTRODUCTION

1.1 Introduction

Maize or corn (*Zea mays*) belongs to the family of grasses (*Poaceae*). It stands third after wheat and rice in the world's cereal production (Bukhsh, 2010). It is cultivated globally as one of the most important cereal crops. Maize is a versatile crop grown over a range of agro-climatic zones. It is cultivated successfully in the subtropical, tropical and temperate regions of the world (Bukhsh *et al.*, 2003).

Sweet corn (*Zea mays* var. saccharata) is widely used for human consumption throughout the world and even eaten when immature. It differs from all other types of maize, because it produces and retains large amounts of sugar in the kernels, hence its name 'sweet corn'. In Malaysia, sweet corn is a popular crop that is cultivated over a wide range of conditions. It is an excellent source of sugars, dietary fibre, vitamin-C, beta-carotene, niacin, in addition to calcium and potassium. According to Evensen and Boyer (1986), sweetness is the most important factor for consumer satisfaction in sweet corn. Sweet corn occupies about 1.06 million ha of harvested area in the world for the fresh, frozen and canned food industries (FAO, 2005).

The productivity of maize largely depends on its nutrient requirements and management particularly that of nitrogen, phosphorus and potassium. The low fertility status of most tropical soils reduces maize production as maize has a strong exhausting effect on the soil. In plots with inadequate nutrients, it has been generally observed that maize fails to produce good grain (Adediran and Banjoko, 2003). Inorganic fertilizer exerts a strong influence on plant growth, development and yield thus it leads to larger dry matter production which results in luxuriant growth

(Stefano *et al.,* 2004 and Obi *et al.,* 2005).

Previous studies have shown that when subjected to different levels of potassium fertilizer, it resulted in different responses in maize growth (Echarte *et al.*, 2000; Maddonni and Otegui, 2004). This is because potassium plays a vital role in the growth and development of maize. According to Hickman (2002), potassium helps plant to uptake nitrogen from soil and increases the grain yield of maize.

In addition, the usage of inorganic fertilizer alone may degrade the soil quality and fertility. Poultry manure is a natural fertilizer which possesses high nitrogen content and other essential plant nutrients, and serves as soil amendment by adding organic matter (Hussein, 1997). It is because poultry manure act not only as supplier of nutrient content in the soil for crop growth but improves the soil structure and fertility.

Biochar provides a unique opportunity to improve soil fertility and nutrient-use efficiency using locally available and renewable materials in a sustainable way. Adoption of biochar management does not require new resources, but makes more efficient and more environmentally conscious use of existing resources. In many regions, loss in soil productivity occurs despite intensive use of agrochemicals, concurrent with adverse environmental impact on soil and water resources (Foley *et al*, 2005). Hence, biochar is able to play a major role in expanding options for sustainable soil management by improving upon existing best management practices, not only to improve soil productivity but also to decrease environmental impact on soil and water resources.

In Malaysia, most of its soil consists of Oxisols and Ultisols which are very common especially in the upland areas, occupying about 72 % of the country's land area which includes in the mineral acid soil with the pH ranging from 4 to 5. Under such condition, aluminium is present at a toxic level for crop production. Malaysia grows oil palm, rubber and cocoa on Ultisols and Oxisols, which are dominated by kaolinite, gibbsite, goethite and hematite (Shamshuddin and Ismail 1995; Anda *et al.* 2008). The charges on the mineral surfaces change following changes in pH. The soils are sometimes used for field crops, but their yields are limited by low pH, high aluminium and calcium and/or magnesium deficiencies (Shamshuddin *et al.* 1991).

They are by nature devoid of basic cations (Ca and Mg) and available P (due to fixation by the oxides) and hence, their productivity is generally considered as low. Since Silabukan soil is in the Ultisol soil series, this type of soil is very poor in performance for planting corn and low in fertility for crop production.

This study aimed to increase the performance of low fertility of Silabukan soil by incorporating potassium fertilizer and chicken manure biochar in order to enhance Improved Mas Madu productivity and performance through its growth, yield and eating quality.

1.2 Justification

This research aimed to increase the fertility of Silabukan soil and at the same time improve the growth, yield and eating quality of Improved Mas Madu sweet corn. Sweet corn is a worldwide commodity crop. Due to its extra sweetness (14-20 % sugar), short duration and impressive returns sweet corn is gaining attractiveness and ample awareness has been created among the farming community. Considering the importance of sweet corn for feeding the world especially in the production of frozen food and commercial needs, the application of potassium fertilizer has an impact on sweet corn growth, yield and eating quality as previous study has shown that potassium can increase the sweetness of sweet corn. The improved sweetness of composite variety of Improved Mas Madu will have a competitive advantage against the hybrid corn in the market. Thus, farmers gain benefits by reducing the cost of purchasing hybrid corn seeds and replacing it with composite seeds as their main choices. Eating quality of fresh or processed whole kernel sweet corn, canned or frozen, is determined by its unique combination of flavour, texture and aroma.

Further, low nutrient content of the Silabukan soil makes it difficult to grow composite maize since its pH ranges from 3.5 to 5.5 which is definitely low and not suitable for growing sweet corn composite seed which needs pH ranging from 5.8 to 6. Hence, liming can be applied by using ground magnesium limestone to overcome the low productivity problems (Shamshuddin *et al.*, 2009) in Silabukan soil.

In a study carried out by Ijaz *et al.*, (2014), application of different levels of potassium showed the significant response of maize protein content in relation to the application of potassium. Also studies carried out by Saidu *et al.*, (2012), showed that performance of maize (*Zea mays* L.) in producing higher grain yield is influenced by complementary use of organic and inorganic fertilizers. Therefore, complementary use of organic and inorganic fertilizers will improve soil nutrients and soil conditions. Organic fertilizers like chicken manure can also serve as soil amendment which can improve the soil structure for better use in the development of agriculture. Hence, the potassium fertilizer and chicken manure biochar will also contribute to ecosystem management since chicken manure biochar is a alternative way of conserving the environment and also saving cost. Thus, chicken manure is incorporated with potassium to plant Improved Mas Madu sweet corn on Silabukan soil with the hope that this combination will improve soil fertility and also the growth, yield and eating quality of sweet corn too.

1.3 Objectives

The objectives of this study are:

1. To evaluate the effect of different rates of potassium incorporated with chicken manure on the growth, yield and eating quality of Improved Mas Madu sweet corn.

2. To evaluate the effect of different rates of potassium incorporated with chicken manure on the fertility of Silabukan soil in the terms of soil pH, nitrogen and phosphorus content.

1.4 Hypothesis

1) Null hypothesis:

H_0: There is no significant difference on the effect of different rates of potassium incorporated with chicken manure on the growth, yield and eating quality of Improved Mas Madu sweet corn.

Hypothesis alternative:

H_1: There is significant difference on the effect of different rates of potassium incorporated with chicken manure on the growth, yield and eating quality of Improved Mas Madu sweet corn.

2) Null hypothesis:

H_0: There is no significant difference on the effect of different rates of potassium incorporated with chicken manure on the fertility of Silabukan soil in the terms of soil pH, nitrogen and phosphorus content.

Hypothesis alternative:

H_1: There is significant difference on the effect of different rate of potassium incorporated with chicken manure on the fertility of Silabukan soil in terms of soil pH, nitrogen and phosphorus content.

CHAPTER 2

LITERATURE REVIEW

2.1 Sweet Corn

Sweet corn (*Zea mays* var. *saccharata*) is a medium plant type that provides green ears in 65 to 75 days after sowing. These are harvested by 35 to 45 days earlier compared to normal grain maize. It is highly prized by corn fanciers due to its succulent and tender kernels with sweet flavour. Sweet corn is consumed in roasted, boiled or raw form and can also be added to salads, among other food ingredients (Jibrin and Sarkin-Fulani, 2011, Akintoye and Olaniyan, 2012). Sweet corn has the ability to produce and retain large amount of sugar within the kernel which makes it distinct from another types of maize (Jibrin and Sarkin-Fulani, 2011). Due to its extra sweetness (14-20 % sugar), short growth duration and impressive returns sweet corn is gaining attractiveness and ample awareness has been created among the farming community. According to Tindall (1983), the kernels are rich in vitamin 'A', phosphorus, thiamine and some trace elements.

Sweet corn is included as a popular commodity among smallholders and consumers and is widely cultivated in Malaysia. In 2001, the acreage of sweet corn in Malaysia was 10,622 ha which comprised 4,899 ha in Peninsular Malaysia, including Kelantan (1,138 ha), Pahang (890 ha) and Johor (775 ha). There are more farmers from Perak, Terengganu and Selangor involved in the production of the sweet corn in those states (Leong, 2005). It is predicted that the present acreage is insufficient to meet demand. Sweet corn offers a stable market and MARDI has released some popular varieties through breeding research programmes like Thai Supersweet in 1981, followed by Yellow Supersweet and Manis Madu (Lee, 1990) in 1987. All of these varieties that have been introduced are well accepted among both farmers and the private sector. In the year 1989, Mas Madu (Wong et al., 1990) was introduced, five years later followed by Improved Mas Madu varieties (Abdul Wahab *et al.,* 1994).

2.1.1 Botanical Description of Improved Mas Madu

In the year 1994, Improved Mas Madu was introduced and it is likely the same as Mas Madu varieties but different in some particular ways as it is the inbred line of the Mas Madu varieties. The kernel of this variety is light yellow in colour and flowering occurs earlier about 48 to 53 days after planting. The average plant height is 165 to 215 cm. The level of sweetness of Improved Mas Madu is high which is between 17 to 19" Brix. Improved Mas Madu sweet corn belongs to the family of Poaceae in the *Zea* genus and completes its life cycle in less than a year. According to Department of Agriculture Pulau Pinang (2013), sweet corn is sold at RM 0.15 per cob and the yield per hectare can reach up to 30,000 units in a year.

2.1.2 Morphology of Maize

Maize belongs to the tribe Maydeae of the grass family *Poaceae*. The genus Zea consists of four species of which *Zea mays* L. is economically important. This genus is monotypic and represented by the single species, Zea mays, which is of economic importance (Rao, 1983). The seeds of sweet corn (*Zea mays* var. *saccharata*) will be wrinkled and transparent when they come to mature stage. Immature seeds contain higher sugar level (water soluble polysaccharide, WSP) than its milk. Sugar content in sweet corn is higher by four to eight times compared to normal corn after 18 to 22 days of pollination (Tracy, 1994).

a) Root System

The root system of maize is deep and fibrous. It has a profusely branched, fine root system. It consists of seminal or temporary roots, crown or coronal roots and brace, prop or aerial roots. The seed root is the first root to come out which is soon followed by seedling roots or generally referred to as seminal roots. Seminal roots consist of the radical and a number of lateral roots which arise at the base of the first node of the stem under the soil surface just above the scutellar node. Permanent adventitious roots that originate from the crown present at the end of mesocotyl is later replaced by the seminal roots. The crowns or coronal roots arise from the basal portion of the stem.

Besides these roots the plant produces 'prop' and 'brace' roots which are adventitious in nature and are produced on the first two or three nodes of the plants above the soil surface. The earth root developed is characterized by prominent lateral growth in the upper foot of the soil after which vertically growing roots become more prominent (Foth *et al.*, 1960).

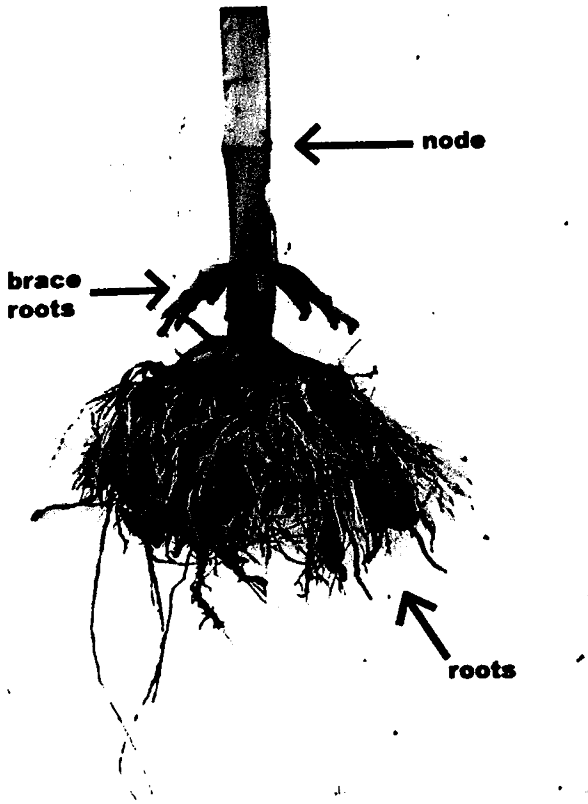

Figure 2.1.2(a): The primary parts of mature corn adventitious roots.
Sources: University of Nebraska-Lincoln (2005)

b) Shoot System

The shoot system is an aerial and erect part of the plant body which grows upwards. It is usually above the soil and develops from plumule of the embryo. It consists of stem, branches, leaves, flowers, fruits and seeds. Maize is a monoecious plant having both male and female inflorescence on the same plant. Male flowers are borne in a tassel at the top of the stem and female flowers are borne inside the young cobs. Maize kernel is one seeded fruit or caryopsis. Seed enclosed within the pericarp consists of the embryo, endosperm and remnants of seed coat and nucellus.

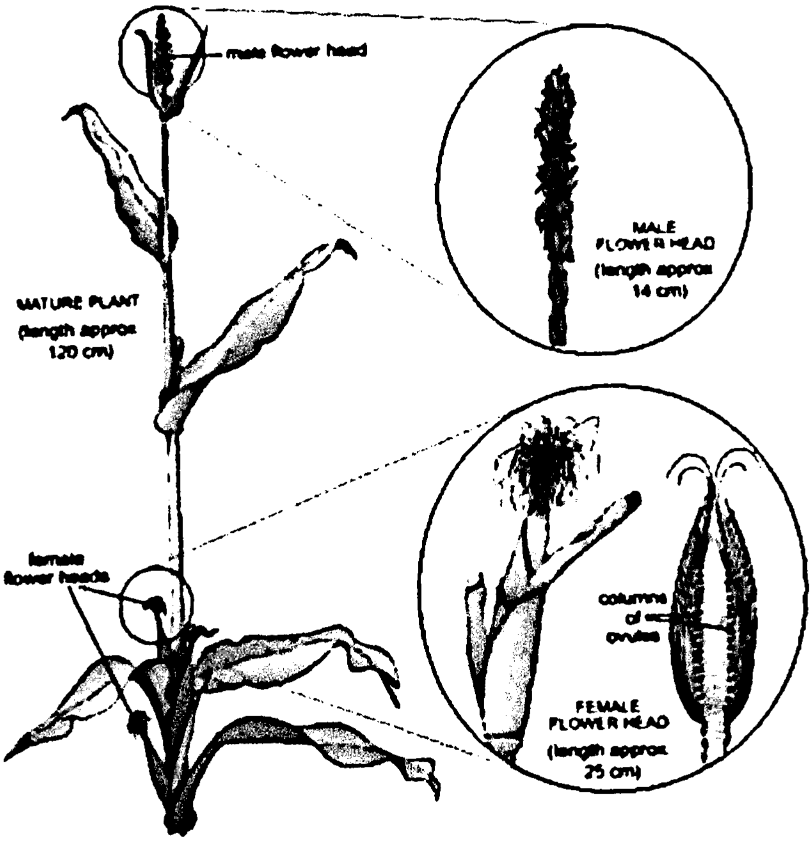

Figure 2.1.2(b): The arrangement and structure of male and female flowers on a maize plant.

Sources: www.open.uk

c) Stem

The stem is cylindrical, solid and is clearly divided into nodes and internodes and is filled with pith. It rises as a prolongation of the plumule (one end of an embryo). It is divided into nodes (point of attachment of leaf) and internodes (regions between two nodes) which bears leaves, branches and flowers on nodes. The internodal parts are flattened on the sides next to the leaf sheath. The plants grow to the height of 1.5 metres to 3 metres depending upon variety. They also bear tillers, if the main shoot is damaged or even otherwise. However it is greatly influenced by soil and climatic conditions. Tillers may develop from nodes below the soil surface. The stem is made up of approximately 12-18 alternating nodes and internodes, and is completely filled with pith. The lateral shoot bearing the main ear develops more or less from the bud on the eighth node above the soil surface. The five or six buds directly below the bud give rise to rudimentary lateral shoots of which one or two develop ears (Appendix A1).

N and P uptake continues at a rapid rate. As the number of ears and kernels has already been determined, it is the kernel size that is affected by conditions during this stage. A low kernel weight will reduce yield.

f) Maturity

Approximately 30 days after silking the plant has reached the maximum dry weight, a stage called physiological maturity. This is where a 'black layer' is noticeable at the tip of each kernel, where cells die and block further starch accumulation into the kernel. At this stage the milk line has completely disappeared. Kernel moisture at physiological maturity is around 30%.

2.1.4 Fertilization and Manuring of Sweet Corn Improved Mas Madu

Maize needs a relatively high level of nitrogen plus moderate amounts of potassium and phosphorus. Fertilizer application should be based on soil test results. As a way of reducing the cost of production, fertilizing and planting is done simultaneously. For planting manually, single fertilizer can be used at the rate of 60 kg Nitrogen, 60 kg P_2O_5 and 60 kg K_2O per hectare in the form of urea, Triple Super Phosphate and Muriate of Potash. All three fertilizers are mixed up together before being distributed into the soils at 3cm depth and 5cm at the each side, right and left rows, then it is covered with the soil. For planting using mechanization, fertilizers are distributed using mechanization or machines. The fertilizer which is recommended for use is compound fertilizers 15:15:15 at the rate of 400 kg/ha. As an additional fertilizer or top-dressing, urea is distributed at the rate of 130 kg/ha. This operation is carried out five weeks after planting (Leong, 2005). Although plants take up Nitrogen in the form of NO3 and NH4 under natural conditions, they can also take up N in the form of urea (Hayness and Goh, 1978).

In the previous study by Gudugi *et al.*, (2012), it was shown that poultry manure is a valuable fertilizer whose application needs to be encouraged for both sustainable soil fertility maintenance and optimum plant growth. An application of poultry manure at 15 t ha for sweet corn is comparable to inorganic fertilizers and significantly better than control (90:60:90 NPK kg ha^{-1} with 20 t ha^{-1} chicken manure biochar). It is because maize tolerates sandy soil, if well supplied with organic

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